

CACHE CREEK TOTAL MAXIMUM DAILY LOAD FOR MERCURY PROBLEM STATEMENT

1 INTRODUCTION

The Federal Clean Water Act (CWA) requires States to identify impaired water bodies and to develop programs to correct the impairments. States refer to the correction program as a “Total Maximum Daily Load” (TMDL) program. This refers to the total maximum daily load of a pollutant that a water body can assimilate and not result in impairments. In order to meet State and Federal requirements, TMDLs must include several key elements including, but not limited to the following: description of the problem, numerical water quality target, analysis of current loads and load reductions needed to eliminate impairments, plan and program of implementation to achieve the needed load reductions, and monitoring to document program progress.

The Central Valley Regional Water Quality Control Board (Regional Board) has determined that Cache Creek, located in Lake, Yolo, and Colusa Counties, is impaired because fish in the Cache Creek have elevated fish tissue levels of mercury. In addition, during storm events, water column concentrations of mercury greatly exceed the California Toxics Rule water quality objectives at numerous sampling sites in Cache Creek and tributaries to the Creek. The primary purpose of this report is to present the Problem Statement, which is the first element of the TMDL. The Problem Statement presents information that explains the overall regulatory framework for this TMDL and provides context for the problem, which is the impairment of Cache Creek by mercury. Regional Board staff will complete the other elements of the TMDL in accordance with the time schedule included in this report.

To meet these objectives, the Problem Statement has six sections:

1. Regulatory Background and TMDL Schedule.
2. Watershed Characteristics and TMDL Scope.
3. Mercury Sources and Effects.
4. Beneficial Uses and Applicable Standards.
5. Available Monitoring Data.
6. References.

2 REGULATORY BACKGROUND

2.1 Clean Water Act 303(d) Listing and Total Maximum Daily Load Development

Section 303(d) of the federal Clean Water Act requires States to:

1. Identify those waters not attaining water quality standards (referred to as the “303(d) list”).
2. Set priorities for addressing the identified pollution problems.
3. Establish a “Total Maximum Daily Load” for each identified waterbody and pollutant to attain water quality standards.

The 303(d) list for the Central Valley is prepared by the Regional Board and approved by the State Water Resources Control Board (State Board) and the USEPA. Waterbodies on the 303(d) List are not expected to meet water quality objectives even if dischargers of point sources comply with their current discharge permit requirements. A TMDL represents the maximum load (usually expressed as a rate, such as kilograms per day [kg/day]) of a pollutant that a waterbody can receive and still meet water quality objectives. A TMDL describes the reductions needed to meet water quality objectives and allocates those reductions among the sources in the watershed. Elements of a TMDL include:

- problem statement;
- numerical water quality target;
- identification and quantification of sources and source loads;
- maximum load of the contaminant that will not adversely impact beneficial uses;
- mathematical linkage between the water quality target and amount of contaminant (a linkage analysis is used to determine the amount by which current pollutant levels must be reduced in order to achieve the maximum load);
- allocation of portions of the necessary load reduction to the various sources; and
- margin of safety that takes into account uncertainties and consideration of seasonal variations.

A problem statement provides the context and background for the TMDL (USEPA, 2000a) by identifying the water body segments and pollutants being addressed by the TMDL, selecting the relevant water quality standards, describing the basis for the 303(d) listing, and providing an overview of the characteristics of the watershed. To establish water quality objectives under Porter-Cologne, Regional Board staff must consider the environmental characteristics of the watershed. Therefore, the problem statement should include a description of characteristics such as land use, precipitation and runoff patterns, soil type, and hydromodification.

2.2 Porter-Cologne Basin Plan Amendment Process

In general, the Regional Board will develop a water quality management strategy for each waterbody and pollutant in the Central Valley identified on California's 303(d) List. The management strategy will include several phases:

- TMDL Development: involves the technical analysis of the sources of pollutant, the fate and transport of those pollutants, the numeric target(s), and the amount of pollutant reduction that is necessary to attain the target.
- Implementation Planning: involves an evaluation of the practices and technology that can be applied to meet the necessary load reductions, the identification of potentially responsible parties, a description of the implementation framework (e.g., incentive-based, waste discharge requirements, and prohibitions), a time schedule for meeting the target(s), and a consideration of cost.
- Basin Planning: focuses on the development of a Basin Plan Amendment and a Functionally Equivalent Document for Regional Board consideration. The Basin Plan Amendment will include those policies and regulations that the Regional Board believes are necessary to attain water quality objectives. The Functionally Equivalent Document includes information and analyses required to comply with the California Environmental Quality Act.
- Implementation: focuses on the establishment of a framework that ensures that appropriate practices or technologies are implemented (§13241 and §13242 of the Porter-Cologne Water Quality Act), including those elements necessary to meet federal TMDL requirements (CWA Section 303(d)).

The Basin Plan Amendment is legally applicable once the Regional Board, State Board, Office of Administrative Law, and the USEPA approve it.

2.3 Timeline and Process for the Cache Creek Mercury Management Strategy

Regional Board Staff is currently working on the TMDL Development phase of the Cache Creek mercury management strategy. This phase should be complete in summer 2003 with the release of the TMDL Report. The Implementation Planning phase will rely heavily on the evaluation of remedial options conducted by the USEPA's Superfund program for the Sulfur Bank Mine site at Clear Lake and the CALFED grant for Harley Gulch and Sulfur Creek. The results of USEPA's evaluation, and other public input on implementation options, could provide support for modification of the recommendations in the TMDL Report. The proposed Basin Plan Amendment would contain any modifications to the TMDL Report, along with the accompanying Functionally Equivalent Document and staff report, which Regional Board staff will present to the Regional Board for adoption. Should an evaluation of implementation options indicate that Cache Creek beneficial uses could not be reasonably attained, Regional Board Staff

may prepare a Use Attainability Analysis as part of the Basin Plan Amendment. Regional Board Staff anticipates proposing a Basin Plan Amendment to the Regional Board by December 2004.

Regional Board Staff intends to seek public input throughout the TMDL Development and Implementation Planning phases. As Regional Board Staff develops documents related to preparation of the Basin Plan Amendment, formal public workshops and hearings will be held.

3 WATERSHED CHARACTERISTICS AND TMDL SCOPE

Cache Creek drains a 0.7 million-acre watershed in the Coast Range of California. The scope of the TMDL encompasses the 81-mile reach between Clear Lake Dam (on the South Fork of Cache Creek) and the Cache Creek Settling Basin (adjacent to the Yolo Bypass) (Figures 1 and 2). The upper Cache Creek basin (above the town of Rumsey) is mostly undeveloped land that contains chaparral and shrub oak habitat and is primarily used as rangeland (Foe and Croyle, 1998). The upper basin is naturally divided into three sub-basins: North Fork (Cache Creek), South Fork (Cache Creek), and Bear Creek. The three waterbodies flow year round. Dams at Indian Valley and Clear Lake control flows in the North Fork and South Fork, respectively. Both the Clear Lake and Indian Valley reservoirs trap winter storm runoff for release during the irrigation season. Annual irrigation storage from the two reservoirs may be as much as 393,000 acre-feet with Clear Lake providing 80 percent of the water (Sorensen and Elliott, 1981). Bear Creek is not dammed. The gradient of Cache Creek along the 33-mile reach between Clear Lake (~1,320 feet above sea level [asl]) and Rumsey (420 feet asl) is steep, dropping approximately 27 feet per mile (USGS, 1958-1992). This drop is sufficient to ensure good sediment transport during all but the lowest flow periods. Large areas of the upper basin are highly erosive (Foe and Croyle, 1998).

There are three inactive mercury-mining districts in the upper watershed area: Clear Lake, Sulfur Creek, and Knoxville mining districts (Montoya and Pan, 1992; Buer et al., 1979). The Clear Lake district includes the Sulfur Bank Mercury Mine at Clear Lake, which is a U.S. Environmental Protection Agency (USEPA) Superfund site. The Sulfur Creek district includes the Elgin, Empire, Abbott, and Wide Awake mines. These drain predominately to Bear Creek. The Knoxville District is in both the Putah and Cache Creek watersheds. The Reed Mine is in the Knoxville District and is on Davis Creek, a tributary to Cache Creek above the confluence of Bear Creek. The Homestake Mining Company constructed Davis Creek Reservoir as a local water source for the nearby McLaughlin Gold Mine and remediated much of the Reed Mine site to reduce off-site movement of mercury. Researchers have documented that Davis Creek

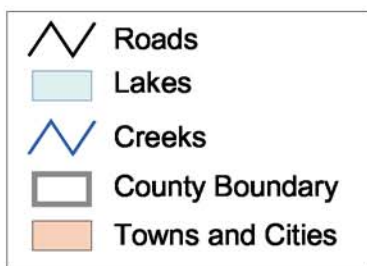
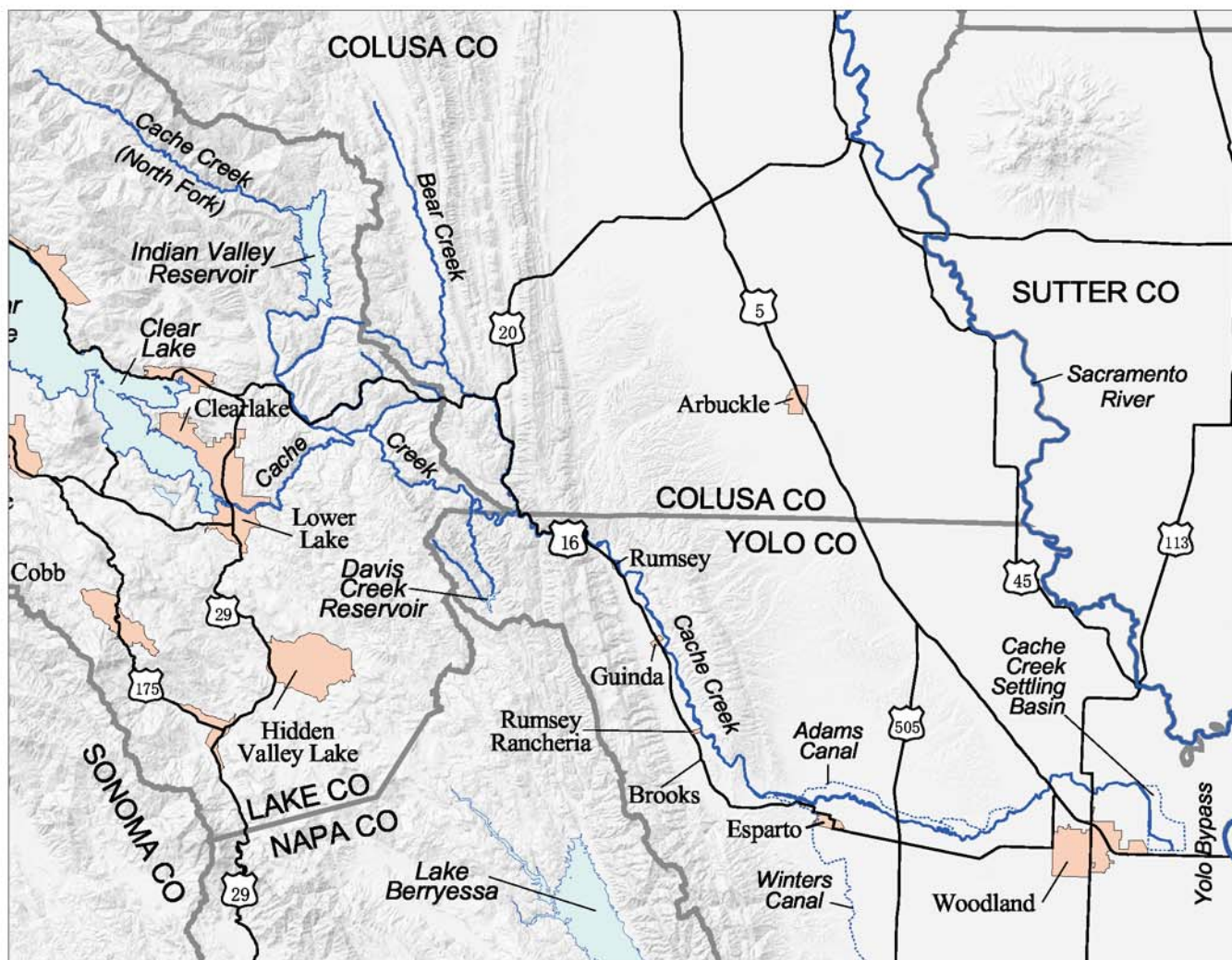


Figure 1. Overview of the Cache Creek Watershed

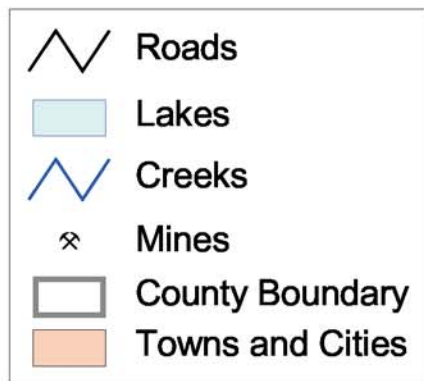
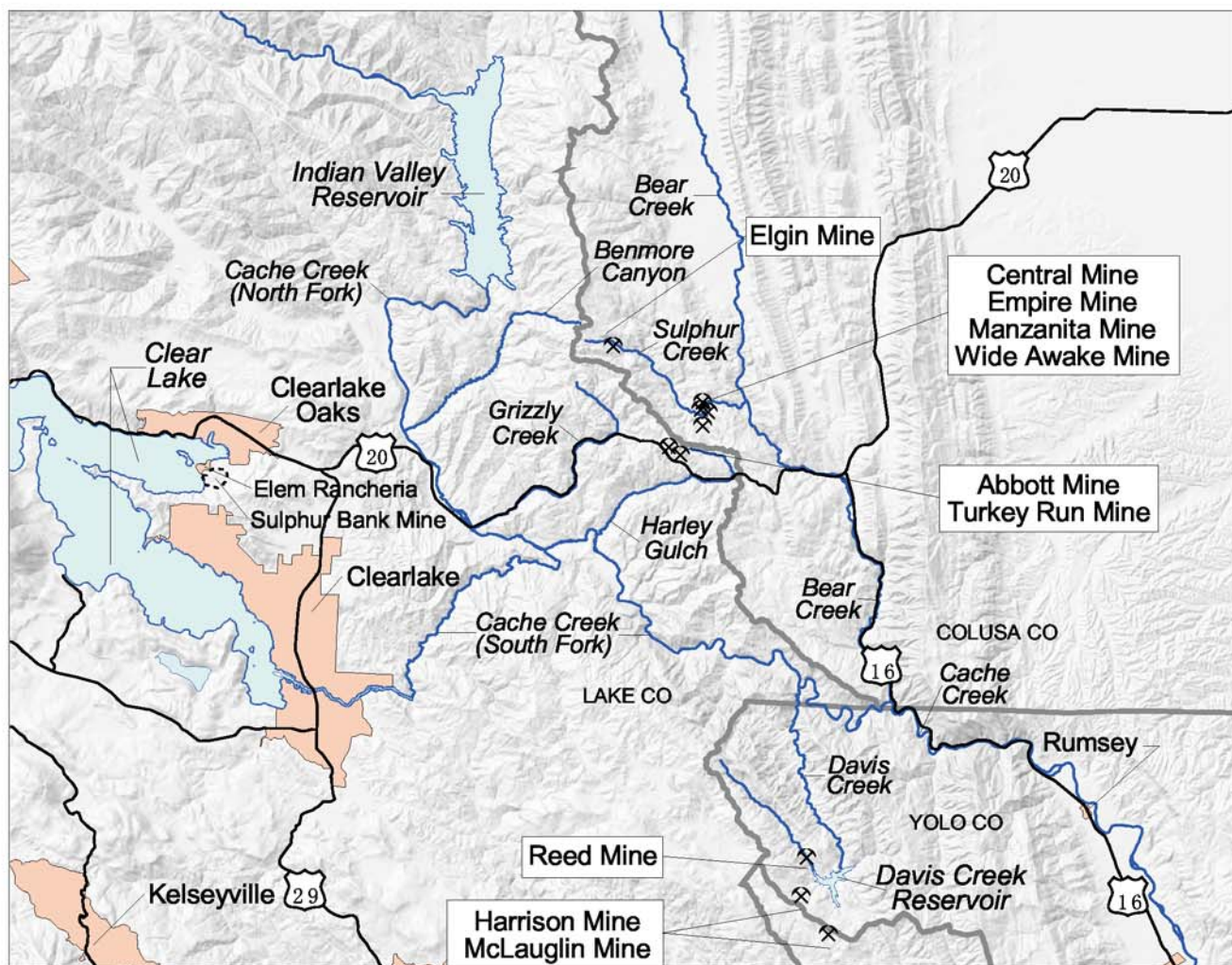


Figure 2. Cache Creek Watershed Mines and Tributaries Discussed in Text

Reservoir traps and settles as much as 200-300 kilograms per year (kg/yr) of mercury eroding from the inactive Reed Mine (Slotton, 1991; Reuter et al., 1996).

The lower Cache Creek basin (downstream of Rumsey) is intensely farmed with mostly row, orchard, and rice cultivation (Foe and Croyle, 1998). An inflatable dam is constructed at Capay (approximately 15 miles downstream of Rumsey) during each irrigation season so that water may be diverted into the Winters and Adams canals. During the peak of the irrigation season, much of Cache Creek below Capay Dam is dry except where the groundwater table is high (Foe and Croyle, 1998). The streambed is broad and flat in the 30-mile reach between Capay Dam (~220 feet asl) and the Settling Basin (40 feet asl), dropping approximately 6 feet per mile. The broad flat flood plain ensures continuous erosion and redeposition of sediment during all but the highest flows. Several tailwater irrigation return flows enter above the town of Yolo providing some discharge from the lower basin to the Yolo Bypass during the dry season.

Several towns and small communities are located within the Cache Creek watershed. Clearlake and Rumsey are located in the upper basin. Guinda, Brooks, Capay, Esparta, and Woodland are located in the lower basin. In addition, the Rumsey Band of the Wintun Indians runs the Rumsey Rancheria approximately 15 miles south of Rumsey in the Capay Valley. The local economy is heavily dependent upon agriculture and tourism. In addition, industrial plants and distribution centers are developing in Woodland, which is the largest town in the watershed.

Precipitation at Brooks for the 1986 to 2000 period typically averaged less than 20 inches per year; however, precipitation exceeded 30 inches per year during four above-average wet years. The majority of rain typically falls between November and March. During the winter, snow occasionally falls in the mountains above the 3,000-foot elevation. Mean annual temperatures for the Cache Creek region are approximately 62 degrees Fahrenheit (°F), with summer temperatures exceeding 100°F and winter temperatures dropping below freezing.

The upper portion of the Cache Creek watershed begins in the Clear Lake basin, which is located in the northern Coast Range geomorphic province, approximately 60 miles east of the San Andreas Fault. The Clear Lake basin is a fault-bounded subsiding depression, believed to be a pull-apart basin related to a releasing bend in the San Andreas Fault. The regional bedrock of the Coast Range consists of a structurally complex group of rocks known as the Franciscan Formation, which formed during the Late Jurassic to Cretaceous period when sediments on the sea floor were scraped off and piled onto the

continent as the Pacific plate was subducted beneath the North American Continental plate. Regional volcanic activity since that time may be related to the extensional faulting in the Clear Lake basin. The shallow magma chamber beneath the Geysers-Clear Lake area is the source of geothermal activity throughout the region. The U.S. Geological Survey (USGS) has mapped numerous hot springs discharging in the area. A large number of these springs flow directly into drainages in the Cache Creek watershed.

The lower portion of the Cache Creek watershed extends eastward into the Great Valley Sequence, a sequence of deep marine siliciclastic sediments that were deposited in the Great Valley fore-arc basin from the late Jurassic to Cretaceous. Late Tertiary marine and Miocene to recent non-marine sediments overly the Great Valley sequence. Thrust faulting of these units (related to compressional stresses within the San Andreas fault system) beginning in the late Tertiary have formed more or less parallel mountain belts that mark the eastern extent of the Coast Range in the region surrounding the Cache Creek watershed.

4 MERCURY SOURCES AND EFFECTS

4.1 Mercury Sources in the Cache Creek Watershed

The Cache Creek watershed is in the Coast Ranges, a region naturally enriched in mercury. Active geothermal vents and hot springs deposit mercury, sulfur, and other minerals at or near the earth's surface. Most of the mercury deposits in California occur within a portion of the Coast Ranges geomorphic provinces extending from Clear Lake in the north to Santa Barbara County in the south. Approximately 90% of the mercury (roughly 104 million kilograms) used in the United States between 1850 and 1988 was mined in the Coast Ranges of California. Much of the mining and extraction occurred before 1890 when mercury processing was crude and inefficient. Researchers estimate that approximately 34.5 million kilograms of mercury was lost to the environment from historic mercury mining activity (Churchill, 1999). As a result, high levels of mercury are present in some streams, lakes, and reservoirs in the Coast Range, in the Sacramento River, and in the Sacramento – San Joaquin River Delta.

Sources of mercury entering Cache Creek include geothermal springs, agricultural runoff, erosion of naturally mercury-enriched soils and excavated overburden and tailings from historic mining operations, and atmospheric deposition. Although mercury in Cache Creek derives from several sources, available

data indicate that the majority of mercury exported from the Cache Creek watershed derives from discharges of mercury from historic mining operations in the upper basin (Foe and Croyle, 1998).

Regional Board staff determined that the largest mercury loads were exported from the upper basin of Cache Creek after storms (Foe and Croyle, 1998). To identify the major sources of mercury in the upper basin, staff conducted five intensive surveys during storm flow events between January 1997 and February 1998 (Foe and Croyle, 1998). Three surveys took place in Bear Creek and the North Fork, and two took place in Cache Creek Canyon (between the North Fork – South Fork confluence and the Bear Creek inflow). Staff collected water samples from tributaries and from locations up and downstream of tributary inflows to ascertain whether the tributaries enhanced or diluted mercury concentrations in the North Fork, Bear Creek, and Cache Creek Canyon.

Sulfur Creek appeared to be the major source of mercury in Bear Creek. Sulfur Creek is the largest tributary to Bear Creek and drains a 10-square mile area that includes the inactive Central, Wide Awake, Elgin, and Manzanita mercury mines (Figure 2). The drainage has several active geothermal springs that may also be sources of mercury. Mercury concentrations during storms in Sulfur Creek ranged between 2,000 and 12,000 nanograms per liter (ng/L). These concentrations were sufficient to increase downstream mercury concentrations in Bear Creek fourfold to sixfold.

Benmore Canyon Creek and Grizzly Creek appeared to be the major sources of mercury in the North Fork. Both waterways are ephemeral and drain 7- to 8-square mile watersheds on the western slope of the Sulfur Creek Mercury Mining District (Figure 2). Neither watershed is known to contain geothermal springs or mines. Mercury concentrations in each watershed ranged from 2,000 to 3,000 ng/L during storm events. This concentration is nine to twelve times greater than concentrations measured upstream on the North Fork Cache Creek. The inflow from the two drainages increased mercury concentrations in the downstream North Fork by twofold to threefold.

The Cache Creek Canyon is mostly inaccessible by road. Several float trips were attempted down the canyon to determine major mercury sources, but these were largely inconclusive because it was determined that these trips were unsafe at the high flows characteristic of major loading events. Many of the tributary inputs are ephemeral and had little-to-no flow during the float trips. Harley Gulch and Davis Creek are tributary inputs to the section of the canyon that is accessible by road. Harley Gulch drains a 3-square-mile watershed that includes Abbott Mine and Turkey Run Mine. Two water samples collected from Harley Gulch had mercury levels ranging between 146,000 and 360,000 ng/L. The ephemeral

drainage appeared to have a flow of approximately 50 cubic feet per second during both sampling efforts, but how much its mercury concentration increased the mercury levels downstream in Cache Creek could not be determined. No mercury concentration estimates were available for Davis Creek, a 9-square-mile watershed that contains the Reed Mine. Previously, researchers estimated that discharge from this watershed carries 200-300 kg/year (Slotton, 1991; Reuter et al., 1996). The material is now being trapped in the Davis Creek Reservoir; however, it is possible that previously discharged sediment contaminated with mercury may have settled in flatter portions of the creek downstream of the reservoir and may erode during high flows.

Regional Board staff and contractors are performing monitoring and analytical efforts funded with a two-year CALFED mercury grant (CALFED Directed Action #99-B06) to provide source information necessary for the Cache Creek TMDL control program. The goals of these ongoing tasks funded by the CALFED grant are to:

- determine the inorganic and methyl mercury loads from identified major sources,
- determine the relative methylation potential of sediment discharged from each site,
- locate the “hot spots” on each mine site that require remediation, and
- determine the cost of remediation.

4.2 Mercury Chemistry and Accumulation in Biota

Mercury (Hg) can exist in various forms in the environment. Physically, mercury may be present in air as mercury vapor, dissolved in the water column, or associated with solid particles in air, water, or soil. Chemically, mercury can exist in three oxidation states: elemental (Hg^0), mercurous ion (monovalent, Hg^+), or mercuric ion (divalent, Hg^{+2}). Ionic mercury can react with other chemicals to form both organic and inorganic compounds and can be converted by sulfite reducing bacteria to more toxic organic compounds, such as methylmercury or dimethylmercury. Important factors controlling the conversion rate of inorganic to organic mercury include temperature, percent organic matter, redox potential, salinity, pH, and mercury concentration. Neither the primary locations of methyl mercury production nor the principal factors controlling methylation are yet known for any location in the Central Valley.

Both inorganic mercury and organic mercury can be taken up from water, sediments, and food by aquatic organisms. Because organic mercury uptake rates are generally much greater than rates of elimination,

methylmercury concentrates within organisms. Low trophic level¹ species such as phytoplankton obtain most mercury directly from the water. *Bioconcentration* describes the net accumulation of mercury directly from water. The *bioconcentration factor* is the ratio of mercury concentration in an organism to mercury concentration in water. However, predatory species such as piscivorous (fish-eating) fish and birds obtain most mercury from mercury-containing prey rather than directly from the water (USEPA, 1997b). A *bioaccumulation factor* describes the degree to which mercury accumulates from water and prey, relative to mercury concentration in the water. Compounds *bioaccumulate* when rates of uptake are greater than rates of elimination.

Repeated consumption and accumulation of mercury from contaminated food sources results in tissue concentrations of mercury that are higher in each successive level of the food chain. This process is termed *biomagnification*. Methylmercury readily accumulates in fish due to efficient uptake from dietary sources and low rates of elimination. The proportion of total mercury that exists as the methylated form generally increases with level of the food chain, approaching greater than 90% in top trophic level fish (Nichols et al., 1999). This occurs because inorganic mercury is less well absorbed and/or more readily eliminated than methylmercury. Field studies indicate that diet is the primary route of mercury uptake by fish (Wiener and Spry, 1996). Methylmercury is the predominant form of organic mercury present in biological systems. Dimethylmercury, which is an unstable compound that dissociates to methylmercury at neutral or acid pH, is not considered a concern in freshwater systems (USEPA, 1997a).

Diet is the primary route of methylmercury exposure for organisms that consume fish and aquatic invertebrates. Although a few studies have indicated that methylmercury impairs reproduction of some fish (Huber, 1997; Wiener and Spry, 1996), the greatest concern for mercury toxicity is in higher trophic-level organisms that consume aquatic life. The aquatic food web provides more than 95% of humans' intake of methylmercury (USEPA, 1997a).

To summarize, mercury is of concern in the Cache Creek watershed (and in the downstream Sacramento-San Joaquin Delta Estuary) because it biomagnifies in aquatic food webs and can become a human and wildlife health concern when humans and wildlife eat higher trophic level fish. Factors that promote

¹ Trophic levels are the hierarchical strata of a food web characterized by organisms that are the same number of steps removed from the primary producers. The USEPA's 1997 Mercury Study Report to Congress used the following criteria to designate trophic levels based on an organism's feeding habits:

Trophic level 1: Phytoplankton.

Trophic level 2: Zooplankton and benthic invertebrates.

Trophic level 3: Organisms that consume zooplankton, benthic invertebrates, and phytoplankton.

Trophic level 4: Organisms that consume trophic level 3 organisms.

mercury accumulation in fish tissue are not well understood. One method of evaluating the efficiency of mercury bioaccumulation in different basins is to compare concentrations in biota of similar age and trophic level. Researchers assume that mercury biomagnifies more efficiently in watersheds where similar taxa contain higher mercury concentrations.

4.3 Toxicity of Mercury

4.3.1 Effects on Humans

Mercury is a potent neurotoxin in humans. Developing fetuses and young children are at greatest risk of toxicity from mercury (NRC, 2000). Although the inhalation of elemental mercury fumes can cause harm, exposure to levels of concern most frequently occurs through the consumption of methylmercury in fish tissue. Researchers have documented the toxicity of mercury to humans in populations consuming contaminated fish (Davidson et al., 1998; Grandjean et al., 1997; Tsubaki and Irukayama, 1977) and grains treated with methylmercury-containing fungicide (Bakir et al., 1973). Consumption of highly contaminated fish caused multiple effects, including tingling or loss of tactile sensation (paresthesia²), loss of muscle control, blindness, paralysis, birth defects, and death. Children whose mothers ate fish during pregnancy may be at risk for more subtle behavioral and neurodevelopmental impairments (Crump et al., 1998; Davidson et al., 1998; NRC, 2000). Researchers also determined that children who eat fish themselves are more sensitive to mercury than adults are because their neural systems are still developing and they tend to consume more fish per body weight than adults consume (Grandjean et al., 1999; Mahaffey, 1999). Effects in children exposed early in development appear at dose levels five to ten times lower than dose levels associated with toxicity in adults (NRC, 2000).

Although the largest body of literature addresses effects of mercury on neurodevelopment, studies have found impairment of other human organ systems as well. Exposure to mercury causes reduced fertility, adverse cardiovascular effects, and immunotoxicity, and to alter cell division (NRC, 2000; Speirs and Speirs, 1998).

Effects of mercury are dependent upon the dose received. Levels of mercury in fish from Cache Creek are much lower (0.15 to 1.5 microgram per gram [$\mu\text{g/g}$], wet weight for top predator fish³) (CVRWQCB, 1985; Slotten et al., 2001) than levels in fish that poisoned consumers in Minamata Bay, Japan (mercury levels up to 50 $\mu\text{g/g}$) (Tsubaki and Irukayama, 1977). There is no current evidence of

² Paresthesia is an abnormal “prickling” sensation in the skin and is an early clinical symptom of neurological damage.

³ Refer to Section 5 for a review of available fish tissue data.

acute or chronic mercury toxicity to humans due to consumption of fish from Clear Lake or Cache Creek. However, researchers have not yet conducted extensive fish consumption and effect studies in the region. Existing fish consumption advisories for Clear Lake, presented in terms of pounds of fish that humans can safely consume, are based upon the risk for average adult consumers of developing a non-fatal, neurologic impairment of paresthesia (Stratton et al., 1987).

4.3.2 *Effects on Wildlife*

Wildlife species also exhibit detrimental effects from mercury exposure. Researchers have observed behavioral effects – such as impaired learning, reduced social behavior and impaired physical abilities – in mice, otter, mink and a primate species (crab-eating macaques) exposed to methylmercury (Wolfe et al., 1998). Researchers have also observed reproductive impairment following mercury exposure in multiple species, including common loons and western grebe (Wolfe et al., 1998), walleye (Huber, 1997), and mink (Dansereau et al., 1999). The San Francisco Bay Toxic Hot Spot Cleanup Plan identified that mercury concentrations in fish tissue in Cache Creek may be sufficiently elevated to endanger piscivorous wildlife (SWRCB, 1999). Principal species at risk are piscivorous birds, small mammals, and possibly predacious fish.

5 BENEFICIAL USES AND APPLICABLE STANDARDS

5.1 Cache Creek Beneficial Uses

Both the Federal Clean Water Act and the State Water Code (Porter-Cologne Water Quality Act) require identification and protection of beneficial uses. The beneficial uses designated in Table II-1 of the Water Quality Control Plan for the Sacramento and San Joaquin Basins (CVRWQCB, 1998) are intended to meet all applicable State and Federal requirements. Table 1 lists the existing and potential beneficial uses of Cache Creek. Cache Creek provides habitat for warm and cold water species of fish and the aquatic communities associated with them. In addition, Cache Creek and associated riparian areas provide valuable wildlife habitat. There is significant use of Cache Creek for swimming, fishing, rafting, and picnicking. In addition, water is diverted from Cache Creek for municipal and industrial water supply and for agriculture use.

Elevated mercury levels in fish from Cache Creek pose a risk for humans and wildlife that consume fish taken from the Creek. Mercury concentrations in Cache Creek frequently exceed water quality objectives

for protection of drinking water, as adopted in the California Toxics Rule. In addition, mercury transported from Cache Creek downstream to Yolo Bypass and the Delta pose a risk in these areas. As has been previously mentioned, Cache Creek is a major source of mercury to the Sacramento-San Joaquin Delta Estuary. Monitoring has demonstrated that in wet years the Creek may contribute half of all the mercury that is transported into the Estuary. Recent work has shown that aquatic organisms immediately downstream of Cache Creek in the Yolo Bypass have some of the most elevated concentrations of mercury in the Estuary. The mercury TMDL control program for Cache Creek must also consider actions needed to protect downstream beneficial uses in the Estuary.

Table 1. Existing and Potential Beneficial Uses of Cache Creek (CVRWQCB, 1998)

Beneficial Use	Status
Municipal and domestic supply (MUN)	existing ^(a)
Agriculture – irrigation and stock watering (AGR)	existing
Industry – process (PROC) and service supply (IND)	existing
Recreation – contact, canoeing, and rafting (REC-1) and other non-contact (REC-2)	existing
Freshwater habitat (Warm)	existing ^(a)
Freshwater habitat (Cold)	potential ^(a)
Spawning (SPWN) – warm and cold	existing
Wildlife habitat (WILD)	existing ^(a)

(a) Beneficial uses impaired by mercury in Cache Creek.

5.2 Water Quality Objectives

The narrative water quality objective for toxicity in the Basin Plan states, in part, “All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life.” The narrative toxicity objective further states that “The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the USEPA, and other appropriate organizations to evaluate compliance with this objective.” (CVRWQCB, 1998)

Researchers have developed numeric criteria for mercury in fish tissue and water for both human health and wildlife protection. The National Academy of Sciences-National Academy of Engineering (NAS) numeric mercury guideline of 0.5 µg/g (parts per million [ppm]) (NAS, 1973) applies to whole,

freshwater fish and marine shellfish. The NAS criterion applies to wildlife protection. The United States Food and Drug Administration (USFDA) action level of 1.0 ppm (USFDA, 1984) applies to the edible portion of commercially caught freshwater and marine fish; the action level applies to human health. The USEPA recently established a criterion of 0.3 ppm methylmercury in the edible portions of fish for protection of human health (USEPA, 2001). The USEPA has also established wildlife criteria for the Great Lakes Water Quality Initiative (USEPA, 1995) and the Mercury Study Report to Congress (USEPA, 1997a). These USEPA criteria suggest that a range of mercury in fish tissue of 0.08 ppm (trophic level 3 [TL3] fish) to 0.35 ppm (trophic level 4 [TL4] fish) should be protective of wildlife. Because wildlife generally consumes lower trophic level (and smaller) fish, the human health and wildlife criteria are not directly comparable.⁴

The USEPA and the California Department of Health Services determined a primary maximum contaminant level (MCL) of 2.0 micrograms per liter ($\mu\text{g/L}$) (2,000 ng/L) of mercury for drinking water (Marshack, 2000). The USEPA established a recommended ambient water quality criterion of 1.4 $\mu\text{g/L}$ (1,400 ng/L) total mercury (maximum concentration, 1-hour average) for the protection of freshwater aquatic wildlife (USEPA, 1999). In addition, the USEPA promulgated the California Toxic Rule (CTR) in April 2000 (USEPA, 2000b). The CTR contains a water quality objective of 0.05 $\mu\text{g/L}$ (50 ng/L) total recoverable mercury for freshwater sources of drinking water. The CTR criterion protects humans from exposure to mercury in drinking water and contaminated fish. The standard is enforceable for all waters with a municipal and domestic water supply and/or any aquatic beneficial use designation. Cache Creek has such a beneficial use designation. The federal rule did not specify duration or frequency terms; however, researchers have previously employed a 30-day averaging interval with an allowable exceedance frequency of once every three years for protection of human health, which is recommended for this effort (Marshack, personal communication). The USFWS and U.S. National Marine Fisheries Service were concerned that the USEPA's mercury objective in the CTR would not be sufficiently protective of threatened and endangered species. The USEPA has committed to revising its water quality objective to include protection of wildlife. The final water quality value for wildlife protection is not yet known.

⁴ The NAS numeric mercury guideline, USFDA action level, and USEPA criteria are based on analyses of different portions of fish samples. The NAS numeric mercury guideline is based on whole fish because it was calculated to protect wildlife health. In contrast, the USFDA action level and USEPA criteria are based on the edible portions of fish (fillets) because they were calculated to protect human health. The results in Section 5 are for fish fillets unless noted otherwise. Staff assumes that mercury concentrations in fish fillet samples are indicative of whole-body results because Becker and Bigham (1995) found that whole-body mean methylmercury concentrations were 4%, 6%, 40%, and 18% less than mean methylmercury concentrations in fillets from gizzard shad, white perch, bluegill, and smallmouth bass, respectively; only the bluegill data had a statistically significant difference ($P \leq 0.05$, t -test) between methylmercury concentrations in whole body samples and fillet samples.

6 AVAILABLE MONITORING DATA

Fish tissue, benthic invertebrate, and water data indicate that Cache Creek is impaired by mercury. Since 1976, several agencies have monitored mercury in Cache Creek by collecting water, fish tissue, and other biota samples. The sections below summarize the available environmental data and describe the extent of mercury impairment.

6.1 Fish Tissue Data

Between 1976 and 1988, the Toxic Substances Monitoring Program (TSMP) analyzed three TL3 fish samples and seven TL4 fish samples collected from Cache Creek at Brooks, which is approximately seven miles upstream of Capay Dam in the lower basin (SWRCB-DWQ, 1996; Wyels, 1987). The three TL3 fish samples had mercury levels ranging from 0.33 ppm to 0.47 ppm, all of which exceeded the USEPA criteria for wildlife protection (0.08 ppm for TL3 fish) and human protection (0.3 ppm). The seven TL4 fish samples had mercury levels ranging from 0.15 ppm to 0.68 ppm. Five of the TL4 fish samples exceeded the USEPA criterion for human protection (0.3 ppm). Four of the TL4 samples exceeded the USEPA criterion for wildlife protection (0.35 ppm for TL4 fish). Three of the TL4 samples exceeded the NAS mercury guideline (0.5 ppm).

In 1997 Yolo County contracted with researchers from the University of California, Davis (UC Davis) to determine mercury levels in Cache Creek fish (Davis, 1998). UC Davis researchers collected sixty-four large, mature TL3 and TL4 fish from twelve species found in the lower watershed during a five-day period. The fish-tissue samples had mercury concentrations ranging between 0.02 ppm and 1.25 ppm. Although most of the fish sampled were small (<0.5 kg), thirteen samples (20 %) had tissue concentrations that exceeded the NAS mercury guideline (0.5 ppm). Two samples had mercury concentrations above the USFDA action level (1.0 ppm). White crappie (12 samples), Sacramento pikeminnow (1 sample), and smallmouth bass (2 samples) had the highest mercury levels. These TL4 fish had average mercury concentrations of 0.49 ppm, 0.50 ppm, and 0.94 ppm wet weight, respectively. These levels are high enough to warrant concern.

In December 2000, UC Davis researchers collected tissue samples from approximately 200 large fish at diverse locations in the Cache Creek watershed as part of the CALFED mercury grant (Slotten et al., 2001). Tissue samples collected from smallmouth bass in Cache Creek at Rumsey had mercury

concentrations as high as 1.5 ppm. The CALFED mercury grant contains a task for the UC Davis researchers to collect more fish from Cache Creek to better characterize mercury concentrations and for the Office of Health Hazard Assessment to evaluate the human health concerns of the mercury contamination.

The San Francisco Bay Toxic Hot Spot Cleanup Plan identified that mercury concentrations in fish tissue in Cache Creek might be sufficiently elevated to endanger piscivorous wildlife (SWRCB, 1999). Principal species at risk are piscivorous birds, small mammals, and possibly predacious fish. Researchers are collecting more information as part of the ongoing CALFED mercury grant to better identify avian species at risk and a dietary mercury concentration protective of their health.

6.2 Benthic Aquatic Invertebrates

In the spring of 1996, researchers collected benthic invertebrate samples in the upper Cache Creek basin to determine mercury bioavailability (Slotton et al., 1997b). In addition, as part of the ongoing CALFED mercury grant, UC Davis researchers collected benthic invertebrate samples in February, May, and August 2000 to determine whether there is a relationship between aqueous mercury and biotic concentrations (Slotton et al., 2001). The methods for both sampling efforts were analogous to those used in the Sierra Nevada Mountains (Slotton et al., 1997a). The samples came from numerous locations along Cache Creek and its tributaries, including drainages in the Bear Creek and North Fork watersheds. The invertebrate samples with the highest mercury concentrations were associated with known mercury mine drainage at Sulfur Creek, Harley Gulch, and Davis Creek. These mercury concentrations were much higher than any observed in comparable samples from the Sierra Nevada Mountains. The highly localized nature of the contamination was demonstrated by the lower mercury concentrations measured in invertebrates from adjacent streams without mercury mining. Invertebrate mercury concentrations decreased with increasing distance from mine areas. Researchers have observed similar phenomena at the Mount Diablo Mercury Mine in the Coast Range (Slotton et al., 1996) and at Sulfur Bank Mercury Mine in Clear Lake (Suchanek et al., 1997).

The benthic invertebrate studies also suggested that, although Cache Creek invertebrate mercury concentrations are high, much of the large bulk mercury loads observed in the Foe and Croyle's 1998 study may not be easily methylated by sulfate-reducing bacteria while in the upper watershed. Little information is available on the bioavailability of Cache Creek mercury once transported into the Estuary, although cinnabar deposits from mine wastes in both the Philippines

and in the Tyrrhenian Sea have been reported to be transformed to bioavailable forms upon release in the marine environment (Benoit et al., 1994; Baldi and Bargagli, 1982; Baldi et al., 1987 and 1989; Barghigiani et al., 1989). Some of the highest invertebrate mercury concentrations in the Estuary are being reported downstream of Cache Creek in Prospect Slough (Suchanek et al., 1999).

6.3 Water Data

Limited water column mercury information exists for Cache Creek (Foe and Croyle, 1998). Regional Board staff collected water samples from several locations along Cache Creek during the summer irrigation season (April through October) and during non-storm runoff and storm runoff events in the winter season (November through March) between February 1996 and February 1998 (Foe and Croyle, 1998). Table 2 lists the percentage of samples that had mercury concentrations exceeding the CTR criterion (50 ng/L), the primary drinking water MCL (2,000 ng/L), and the USEPA criterion for wildlife protection (1,400 ng/L).

Table 2. Summary of Exceedances of Mercury Criteria in Cache Creek Water Samples
(Source: Foe & Croyle, 1998)

Sampling Location (upstream to downstream)		# of Samples ^(a)	Range of Concentrations (ng/L)	Percentage of Samples Exceeding Criteria	
				CTR Criterion (50 ng/L)	USEPA Wildlife Criterion (1,400 ng/L) & MCL (2,000 ng/L) ^(b)
Upper Basin – North Fork & South Fork	Clear Lake Dam (South Fork)	12	4 to 34	0%	0%
	North Fork @ Hwy 20	12	2 to 1,318	33%	0%
Upper Basin – Cache Creek Canyon	Cache Creek above Bear Creek confluence	11	6 to 3,939	27%	18%
	Bear Creek above Cache Creek confluence	13	19 to 1,290	69%	0%
Lower Basin	Rumsey	12	5 to 2,887	50%	8%
	Capay Dam	4	6 to 4,196	75%	25%
	Road 102 (upstream of Settling Basin)	12	7 to 1,295	67%	0%

(a) Samples were collected during the summer irrigation season and storm and non-storm periods.

(b) Mercury concentrations that exceeded the USEPA wildlife protection criterion (1,400 ng/L) also exceeded the MCL (2,000 ng/L).

Regional Board staff determined that storm runoff events accounted for the majority of the mercury exported from the Cache Creek watershed. Regional Board staff also determined that the majority of mercury appeared to come from Cache Creek Canyon downstream of the North Fork - South Fork confluence. Typical total recoverable mercury concentrations range between 2 and 4,000 ng/L with the highest values occurring in winter storm runoff. Periodic exceedances of the CTR criterion, MCL, and USEPA criterion occur in wet years. Researchers are currently collecting information as part of the ongoing CALFED mercury grant to better define mercury concentrations in Cache Creek and to estimate a water column mercury concentration that is protective of sensitive wildlife.

6.4 Humans

Information that describes the consumption of fish by humans, or mercury levels in humans, is not available for the Cache Creek watershed. However, Regional Board Staff is currently considering coordinating with the San Francisco Estuary Institute to develop a fish consumption study plan similar to that recently completed for the San Francisco Bay. Such a study would provide fish consumption information for inland waterbodies that would be appropriate for the Cache Creek TMDL control program. The default consumption rates provided in the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)* (USEPA, 2000c) would guide staff efforts if site-specific information is not available.

6.5 Mercury Loading Patterns

Regional Board Staff completed a mercury loading study for the Sacramento-San Joaquin Delta Estuary that determined that Cache Creek was a major source of mercury to the estuary. Once Regional Board staff identified Cache Creek as a major source of estuarine mercury, staff undertook synoptic surveys in the Cache Creek watershed during two hydrologic cycles between February 1996 and February 1998 (characterized by wet winters) to attempt to characterize mercury concentrations and loads and to identify sources (Foe and Croyle, 1998). Staff identified three general mercury loading patterns in Cache Creek and classified the patterns according to the period when they were most commonly observed:

- summer irrigation periods,
- winter non-storm runoff periods, and
- winter storm-runoff periods.

The irrigation season occurs during the seven-month period between April and October, the period of the lowest mercury and sediment transport in Cache Creek. The source of most of the water during the

irrigation season during the 1996-98 hydrologic cycles was Clear Lake. According to the limited information available, mercury export rates from the upper Cache Creek basin (above the town of Rumsey) during this period were on the order of 10 to 50 g/day, with most of the mercury coming from Clear Lake. Mercury export from the lower basin was much less, as most of the water (and mercury) was diverted at Capay Dam for irrigation.

Winter non-runoff periods occur between November and March and are characterized by a combination of low baseline flows from Clear Lake (3 to 7 cfs), Indian Valley Reservoir (10 cfs), and Bear Creek (0.5 to 2 cfs), and groundwater seepage. According to the limited information available, mercury export rates for Cache Creek during winter non-runoff periods were on the order of 100 to 1,000 g/day, approximately ten to twenty times more mercury than during the irrigation periods. Much of the mercury appeared to originate from the North Fork.

The third loading pattern was observed during and immediately after large storms, when sufficient rain had fallen to saturate the soil profile and induce sheet runoff. Storm-runoff periods had the shortest duration of the three mercury loading patterns and occurred with a frequency of four to ten times per year. However, the largest mercury loads were exported from the upper basin after storms. Although all three sub-basins in the upper basin exported significant amounts of mercury, the majority of the exported mercury appeared to come from the Cache Creek Canyon (downstream of the North Fork – South Fork confluence and above the Bear Creek inflow). Storm export rates were about 5,000 to 100,000 grams of mercury per day. Overall, infrequent storm runoff events appeared to account for the majority of the mercury exported from the basin.

As part of the ongoing CALFED mercury grant, the USGS is measuring methyl and total mercury concentrations in Cache Creek to determine:

- the efficiency with which methyl mercury is being produced;
- the relationship between total mercury concentrations and efficiency of methyl mercury generation from sediment; and
- the total loads of mercury being transported in the drainage.

The USGS has constructed gage stations on Harley Gulch, Sulfur Creek, and Davis Creek, and is completing additional loading estimates in the basin. In addition, UC Davis is conducting detailed studies at the mine sites in both Harley Gulch and Sulfur Creek to determine the precise locations responsible for off-site mercury movement.

6.6 Summary

Available data indicate that elevated levels of mercury exist in water, fish, and other biota in the Cache Creek watershed. In particular, fish-tissue data collected since 1976 indicate that mercury levels in Cache Creek fish exceed numeric criteria established for human health and wildlife protection. Concentrations of mercury in top-predatory fish species ranged from 0.02 ppm to 1.5 ppm in wet weight of tissue. High levels of mercury in fish are of concern to humans and wildlife that eat fish from Cache Creek. The Regional Board based its decision to list Cache Creek as impaired due to fish tissue data that indicated that mercury levels might be too elevated for human consumption. Elevated levels of mercury have also been found in the water.

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